

Mapping Susceptibility and Spread Associated with the Gypsy Moth

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Abstract

The gypsy moth was originally introduced near Boston in 1868 or 1869, it has been slowly expanding its range mostly to the south and west. Its slow spread through the Northeast can be attributed to the limited dispersal capabilities of this insect (females do not fly). It is inevitable that the gypsy moth will continue to spread to the south and west over the next century. In order to plan for the management of the gypsy moth over the next decade and beyond, there is a need to delimit the distribution of susceptible stands in areas that are currently uninfested. The gypsy moth is a polyphagous insect; North American populations feed on over 300 different shrub and tree species. Despite this wide breadth of host preference, there is considerable variation among trees in their susceptibility to defoliation; the most preferred gypsy moth hosts are in the genus *Quercus*, *Populus* and *Larix*.

Invasions by exotic insects and diseases are one of the most important threats to the stability and productivity of forest ecosystems around the world (Liebhold et al. 1995a; Vitousak et al. 1996). The forests of the eastern US seem to be particularly vulnerable to these invasions; over the last century they have suffered devastating effects by notorious forest pests such as chestnut blight, gypsy moth, and beech bark disease (Mattson 1997). One of the most important steps in the development of effective strategies for management of alien species is to evaluate the risk of future impacts from specific exotic organisms (Byers et al. 2002). The generic activity, "risk assessment" is considered an important component to management of exotics both before and after their arrival in new habitats (Liebhold et al. 1995a). Our research focuses on estimating the expected geographical extent of gypsy moth through 2025 and which areas within that extent will be the most at risk. We used USDA Forest Service Forest Inventory and Analysis (FIA) data to create an estimated surface of basal area that is composed of species preferred by the gypsy moth and historical survey data to model gypsy moth spread.



Introduction

The gypsy moth was originally introduced near Boston in 1868 or 1869, it has been slowly expanding its range mostly to the south and west. Its slow spread through the Northeast can be attributed to the limited dispersal capabilities of this insect (females do not fly). It is inevitable that the gypsy moth will continue to spread to the south and west over the next century. In order to plan for the management of the gypsy moth over the next decade and beyond, there is a need to delimit the distribution of susceptible stands in areas that are currently uninfested.



Figure 1. Gypsy moth larva

We used USDA Forest Service Forest Inventory and Analysis (FIA) data to calculate the basal area at each plot that is composed of susceptible species. The areas with the highest concentration of susceptible forests were in the central and southern Appalachians, the Cumberland Plateau, the Ozark Mountains, and the northwestern lake states. The finding that the gypsy moth has not yet invaded most of the susceptible forests in the US suggests that there still may be considerable value in limiting the future spread of the gypsy moth. It also indicates that both the impacts of defoliation and costs of gypsy moth management are likely to increase in the future.

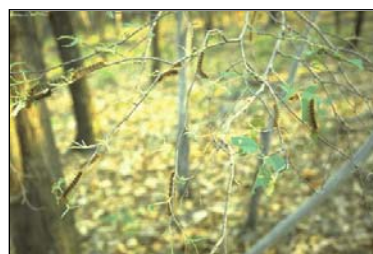


Figure 2. Feeding gypsy moth larvae

Methods

FOREST SUSCEPTIBILITY

The geographical distribution of the suitable habitat for gypsy moth was mapped by interpolation of host species abundance estimated from 93,611 forested FIA plots located throughout the eastern U.S. These data represented the most recent available USDA Forest Service Forest Inventory and Analysis data sampled in each of the thirty-seven states in the Eastwide Database. Host abundance for gypsy moth was measured as basal area/ha of species preferred by the gypsy moth. A species was considered preferred if a preference rating of one was reported by Liebhold et al. (1995b).

The ordinary indicator kriging procedure described by Deutsch and Journel (1998) was performed to interpolate a surface of basal area/ha of species preferred by gypsy moth. Kriging is a geostatistical method that provides unbiased estimates at unsampled locations as weighted averages of values from nearby locations (Issaks and Srivastava 1989; Liebhold et al. 1993). In this analysis we generated maps from the plot data by calculating kriged estimates on a grid of 1- by 1-km cells. Variography and kriging were performed using the GSLIB software library (Deutsch and Journel 1998). One percent of the plots were excluded to use in validating the estimated surfaces.

Forest susceptibility maps were then adjusted for forest density. FIA plots are located randomly but restricted only to forest land area. Therefore, it was necessary to adjust estimates in each 1- by 1-km cell for forest density. This was accomplished using land cover data (National Land Cover Data) which was acquired from the Multi-Resolution Land Characteristics Consortium as a raster matrix of 30- by 30-m cells coded for land use. These data were aggregated to 1- by 1-km to estimate percent forest cover for each cell. Next, the forest susceptibility maps were multiplied by the forest density map to generate forest susceptibility maps adjusted for percent forest cover.

SPREAD PREDICTION

Historical spread of gypsy moth was estimated at 21 km/year by Liebhold et al. (1992). Maps of historical gypsy moth spread are available in Liebhold et al. 1997 (Figure 3). A predicted spread map representing years of expected presence (2001-2025) was generated on a 1- by 1-km grid using the estimated spread rate. Then the number of years of expected presence was divided by 25 (years of possible infestation) to produce a proportion of expected years of gypsy moth presence between 2001 and 2025. The proportion map was multiplied by the adjusted forest susceptibility map to create a map of gypsy moth risk through 2025.

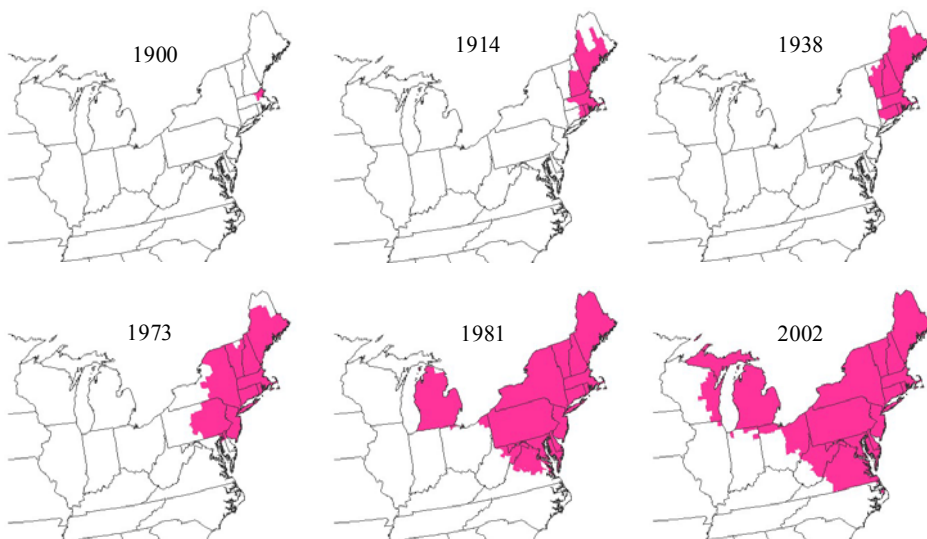


Figure 3. Maps of gypsy moth spread (1900-2002).

Results

Gypsy moth host basal area (m^2/ha) was estimated using ordinary kriging (Figure 4) and then multiplied by the forest density map (Figure 5) to create an abundance map of species preferred by gypsy moth adjusted for forest density (Figure 6). A least-squares regression was run to validate the kriged estimates. The linear model explained about 13% of the variation. Historical spread of gypsy moth was estimated at 21 km/year (Liebhold et al. 1992). A predicted gypsy moth spread map was generated using this historical rate (Figure 8). Finally, the spread map and adjusted host species basal area map were multiplied to create a map of gypsy moth risk for the next 25 years (Figure 9). Gypsy moth defoliation frequency from 1972-2000 is shown in Figure 9.

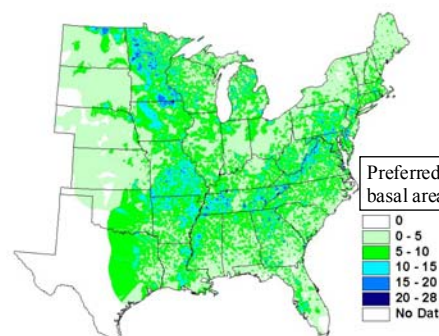


Figure 4. Estimated basal area preferred by gypsy moth(m^2/ha).

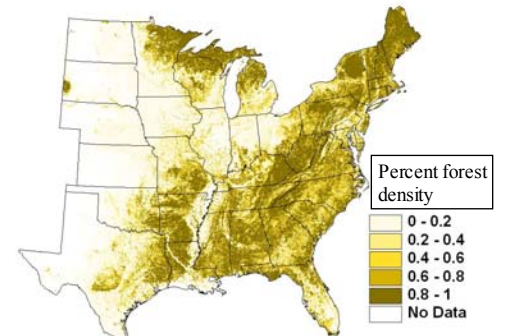


Figure 5. Percent forest density from NLCD data

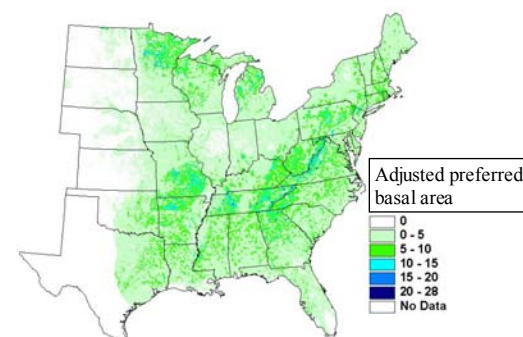


Figure 6. Estimated basal area preferred by gypsy moth(m^2/ha) adjusted for forest density.

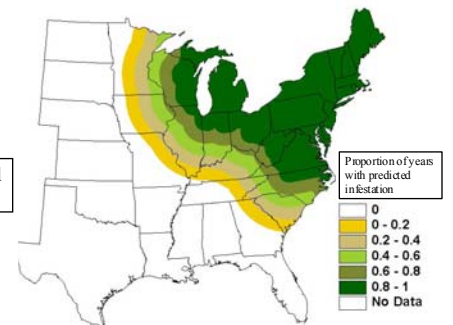


Figure 7. Proportion of years with predicted gypsy moth infestation (2001-2025).

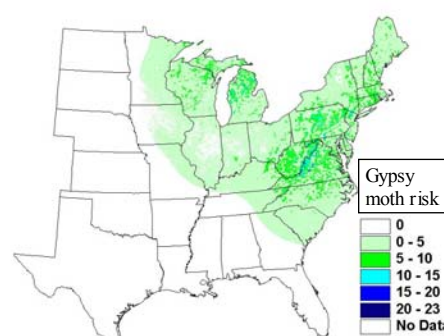


Figure 8. Gypsy moth risk (2001-2025)

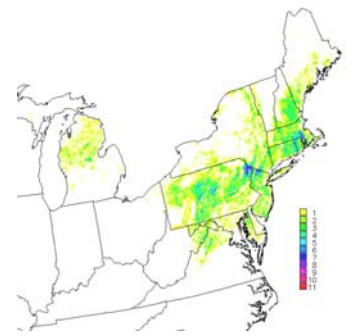


Figure 9. The frequency of gypsy moth defoliation from 1972 to 2000.

Conclusions

- Gypsy moth is currently occupying less than one-third of its' favorable habitat.
- The areas most at risk to gypsy moth over the next 25 years are in the central and southern Appalachians, the Cumberland Plateau, the Ozark Mountains, and the northwestern lake states.

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